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The speciation, distribution, transport, and impact of volatile elements in the Earth's interior

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Volatile elements tend to partition into fluids or melts relative to coexisting minerals. The major volatile elements (e.g., hydrogen and carbon) can have appreciable petrological and geophysical influence disproportionate to their abundance, while the minor volatile elements (e.g., halogens and noble gases) can act as valuable geochemical tracers. Volatile elements, some of which have multiple valence states, are present in variable forms and are distributed unevenly inside the Earth. In the dynamic interior of the Earth, volatile elements are transported through a variety of physical and chemical processes including subduction, devolatilisation, melting and volcanic eruption.

The storage and transport of volatiles can have marked effects on the phase relations (both sub-solidus and at melting), geophysical properties (mechanical strength, seismic velocity, electrical conductivity, etc.) and geochemical behavior (trace element partitioning, isotope fractionation, reaction kinetics, etc.) of the deep Earth. In consequence, volatile elements strongly influence mantle convection and plate tectonics, the formation of the hydrosphere and the atmosphere, and the genesis of mineral and energy resources. Knowledge about the speciation, distribution, transport and effects of volatile elements provides critical clues for understanding the physicochemical conditions and processes in the Earth's interior and the evolution of the Earth as a habitable planet.

In this special issue of Chemical Geology, we have assembled 12 studies on this important topic using petrological-geochemical, experimental, computational, and theoretical approaches. These manuscripts could be characterised by their focus on one of the major volatiles on our planet: water (hydrogen), carbon, sulphur and halogens.

Water. Gu et al. (2017) and Li et al. (2017) report variable yet generally high water contents in peridotite and garnet pyroxenite, which along with other geochemical indicators evidence mantle metasomatism by crust-derived fluids or melts. Asafov et al. (2017) find up to 0.3 wt% H₂O in olivine hosted melt inclusions from 2.7 Ga Komatiites of the Belingwe Greenstone Belt, Zimbabwe, which they explain through interaction between the plume source and a hydrous mantle transition zone. Ni and Zhang (2017) develop a speciation-based (OH against molecular H₂O) general model of water diffusivity in calc-alkaline silicate melts, which reproduces well experimental data and can be applied to modeling bubble growth and gas-driven volcanic eruptions at subduction zones.

Carbon. Abersteiner et al. (2017a) describe the occurrence of multiple generations of monticellite crystals in kimberlites from Canada and Finland. These monticellite crystals provide evidence for large, and previously unobserved, amounts of carbon dioxide degassing during the late stages of kimberlite emplacement that potentially explain their explosive nature. Xue et al. (2017) present a detailed field observations, major element, trace element, and isotopic compositional information and ages of carbonate rocks from Taohuala Mountain in the North China Craton. Based on their observations of cross-cutting relations and flow structures in the field they interpreted these outcrops as evidence of marine carbonate recycling and exhumation extending to ~ 100 km depth during the closure of the Paleo-Qilian Ocean. Sun et al. (2017) postulate the possible presence of diamond and carbonates at the base of the transition zone, as corroborated by ab initio computation of the volumetric properties of carbonate minerals.

Sulphur. Zelenski et al (2017) and Kamenetsky et al (2017) report sulphide-silicate liquid immiscibility in modern arc basalts using the example of Tolbachik volcano in Kamchatka. The authors conducted a thorough petrological study of sulphide globules and silicate melt inclusions embedded into the olivine crystals. Based on the compositions of the coexisting sulphide and silicate melt inclusions, the authors conclude that the origin of the sulphides was related to the local super-saturation of melt with reduced sulphur, and estimate the volatile contents of the parental Tolbachik magmas exhibiting this sulphide mineralisation. Gurenko et al (2017) explore the origin of Plinian eruptions of Chikurachki volcano in the Kurile islands. The authors conclude that the rapid ascent of the volatile-rich magmas to shallow levels could be the main reason for the volcano's explosive eruption. Based on the observed S- and B-isotope and trace element variations in olivine-hosted melt inclusions, the origin of the volatiles is linked to a subduction component representing a mixture of sediment-derived melt and slab-derived fluid added to the depleted mantle wedge.

Halogens. Abersteiner et al. (2017b) analysed melt inclusions hosted by a variety of phases in the Roger kimberlite, Canada, and infer that the parental melt should be strongly enriched in fluorine and chlorine. Wang et al. (2017) investigate whole rock and mineral (apatite and biotite) halogen concentrations in cogenetic I- and A- type Jiuhuashan granites from South China. The A-type granites are found to be more enriched in fluorine, with 0.123 wt% F on average. Even higher halogen concentrations are inferred for the parental granitic magmas, suggesting the loss of halogens from the magma to a fluid phase at a late stage of magma evolution.

It is obvious that this special issue only covers some limited aspects of volatile elements in the Earth's interior. Deep volatiles will continue to be a topic of intensive research in Earth sciences in the years to come, as they are intimately coupled with the workings of the Earth's interior throughout its 4.5 Gyr history.

